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Standard Reference Materials:

Description and Use of a Precision Thermometer for the Clinical Laboratory, SRM 934

B. W. Mangum and J. A. Wise

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Preface

Standard Reference Materials (SRM's) as defined by the National Institute of Standards and Technology (NIST) are well-characterized materials, produced in quantity and certified for one or more physical or chemical properties. They are used to assure the accuracy and compatibility of measurements throughout the Nation. SRM's are widely used as primary standards in many diverse fields in science, industry, and technology, both within the United States and throughout the world. They are also used extensively in the fields of environmental and clinical analysis. In many applications, traceability of quality control and measurement processes to the national measurement system is carried out through the mechanism and use of SRM's. For many of the Nation's scientists and technologists it is therefore of more than passing interest to know the details of the measurements made at NIST in arriving at the certified values of the SRM's produced. The NIST Special Publication - 260 Series, is reserved for this purpose.

The 260 Series is dedicated to the dissemination of information on different phases of the preparation, measurement, certification and use of NIST SRM's. In general, much more detail will be found in these papers than is generally allowed, or desirable, in scientific journal articles. This enables the user to assess the validity and accuracy of the measurement processes employed, to judge the statistical analysis, and to learn details of techniques and methods utilized for work entailing the greatest care and accuracy. These papers also should provide sufficient additional information not found on the certificate so that new applications in diverse fields not foreseen at the time the SRM was originally issued will be sought and found.

Inquiries concerning the technical content of this paper should be directed to the author(s). Other questions concerned with the availability, delivery, price, and so forth, will receive prompt attention from:

Standard Reference Materials Program
National Institute of Standards and Technology
Gaithersburg, MD 20899

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Standard Reference Materials Program

CONTENTS

LIST OF FIGURES

OTHER NIST PUBLICATIONS IN THIS SERIES

McKenzie, R. L., ed., NIST Standard Reference Materials Catalog 1990-91, NIST Spec. Publ. 260 (January 1990)

Michaelis, R. E., and Wyman, L. L., Standard Reference Materials: Preparation of White Cast Iron Spectrochemical Standards, NBS Misc. Publ. 260-1 (June 1964). COM74-11061**

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Geller, S. B., Standard Reference Materials: Calibration of NBS Secondary Standard Magnetic Tape (Computer Amplitude Reference) Using the Reference Tape Amplitude Measurement "Process A-Model 2," NBS Spec. Publ. 260-29 (June 1971). COM71-50282**

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Hicho, G. E., and Eaton, E. E., Standard Reference Materials: A Standard Reference Material Containing Nominally Five Percent Austenite (SRM 485a), NBS Spec. Publ. 260-76 (August 1982). PB83-115568**

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Carpenter, B. S., Standard Reference Materials: Calibrated Glass Standards for Fission Track Use (Supplement to NBS Spec. Publ. 260-49), NBS Spec. Publ. 260-92 (September 1984). PB85-113025**

Ehrstein, J.R., Standard Reference Materials: Preparation and Certification of Standard Reference Materials for Calibration of Spreading Resistance Probes, NBS Spec. Publ. 260-93 (January 1985). PB85-177921**

Gills, T. E., Koch, W. F., Stolz, J. W., Kelly, W. R., Paulsen, P.J., Colbert, J.C., Kirklin, D.R., Pei, P.T.S., Weeks, S., Lindstrom, R. M., Fleming, R. F., Greenberg, R. R., and Paule, R. C., Standard Reference Materials: Methods and Procedures Used at the National Bureau of Standards to Certify Sulfur in Coal SRM's for Sulfur Content, Calorific Value, Ash Content, NBS Spec. Publ. 260-94 (December 1984). PB85-165900**

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DESCRIPTION AND USE

OF A PRECISION THERMOMETER FOR THE CLINICAL LABORATORY, SRM 934

by

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Because of the high sensitivity to temperature of many facets of the clinical laboratory, e.g., in enzyme reactions and in pH and blood gas analysis, there is a need for accurate temperature measurement and its control. In order to help satisfy these needs and to aid in getting a usable and accurate temperature scale into the clinical laboratory, the National Institute of Standards and Technology developed SRM 934. This is a precision thermometer that is calibrated at 0 °C, 25 °C, 30 °C, and 37 °C. The description, calibration, and the procedures for proper usage of this thermometer are discussed.

This SP 260 supersedes SP 260-48 describing both SRMs 933 and 934. SRM 933 will no longer be issued by the SRM Program. This publication is the same as SP 260-48 with the exception that all references to SRM 933 have been removed.

Key words: Clinical laboratory; enzymology; health care; liquid-in-glass thermometers; standard reference material; SRM 934; thermometers.

I. INTRODUCTION

The accurate measurement and control of temperature is of critical importance in many aspects of the clinical laboratory and in the hospital in general. The temperatures at which enzyme rate analyses are

conducted, for example, are very important because of their high sensitivity to this parameter [1-4]. Furthermore, in order to obtain reproducible results within a given clinical laboratory and in order to make a meaningful intercomparison among laboratories, the temperature not only must be carefully controlled but must be known absolutely. In recognition of this situation, the Expert Panel on Enzymes, which was created by the International Federation of Clinical Chemistry Committee on Standards, has recommended [5], among other suggestions in their proposal for I.F.C.C. Reference Methods for Enzymes, that the set point in degrees Celsius of the reaction temperature is to be assigned as a part of the method, that the temperature accuracy must be assured to ±0.05 °C by calibration against the International Practical Temperature Scale of 1968 (IPTS-68) [6], that the temperature variation of the reaction mixture should be held within the open interval -0.05 °C and ±0.05 °C of the set point, and that the choice of reaction temperature for an I.F.C.C. reference method should be 25.00, 30.00 or 37.00 °C. Of course, enzyme reactions are not unique in being sensitive to the temperature; pH and blood gas analyses are two others in a long list that could be mentioned [1]. Although the temperature scale referred to in reference 6 is the IPTS-68, the temperature requirements of that reference will be the same except that the IPTS-68 is superseded by the ITS-90 [7].

Because of these needs and in order to assist in getting a usable temperature scale into the clinical laboratories (and hospitals generally), NIST is providing a precision laboratory thermometer, SRM 934, designed specifically for use in the clinical laboratory. This SRM was produced in cooperation with the Medical Thermometry Program of the Temperature Section in the Heat Division in 1974. Many specifications requested by clinical laboratory personnel concerned with accurate temperature measurements have been incorporated in the design.

II. DESCRIPTION OF THE SRM 934 THERMOMETER

The thermometer comprising SRM 934 is shown in figure 1 and its linear dimensions are as indicated. This is a solid-stem mercury-in-glass type instrument. In order to clarify potential problems in terminology, the principal features of a solid-stem, liquid-in-glass thermometer are shown in figure 2. The stem has a plain front, enameled back, and is of lead glass thermometer tubing 7 mm in diameter. The bulb is also 7 mm in diameter. Nitrogen gas fills the space above the mercury. Special markings consist of a serial number, the manufacturer's name or trade mark, and a 95 mm immersion line. The thermometer has an auxiliary scale from -0.20 °C to +0.20 °C with 0.05 °C subdivisions. The main scale of the thermometer is 24 °C to 38 °C with 0.05 °C subdivisions. The graduations have longer lines at intervals of 0.10 °C and 0.50 °C. In addition, there are numbers every 1 °C.

III. CALIBRATION OF THE THERMOMETER

Each thermometer was tested at the ice point (0 °C) by placing it in an ice bath and at the temperatures above 0 °C by placing it in a stirred-liquid comparison bath [8]. Calibrations were performed at 0 °C, 25 °C, 30 °C, and 37 °C and the temperatures above 0 °C were determined with a standard precision platinum resistance thermometer [9] which was also in the comparison bath. The temperature of the calibration laboratory was 23 °C. The thermometer was read with the aid of a 10 power telescope, which was placed perpendicularly to the thermometer in order to reduce parallax errors. Before each reading, the mercury thermometer was gently tapped to eliminate any error due to a sticking mercury column. The maximum uncertainty associated with any calibration point is no greater than 0.03 °C.

IV. PROCEDURES FOR PROPER USAGE OF LIQUID-IN-GLASS THERMOMETERS

The items discussed in this section are included to focus attention on some of the more common problems encountered in the use of liquid-in-glass thermometers and thus to help assure that the thermometer will be used properly and, thereby, will yield the desired performance. All examples in this paper are given as an aid in the understanding of the subject being discussed, and have not been specifically adapted to SRM 934.

A. CHECK FOR SEPARATED MERCURY COLUMNS AND FOR GAS BUBBLES

Many times, because of rough handling during shipment, separation will occur in the mercury column or gas bubbles will appear in the bulb. When the thermometer is received it should be thoroughly examined for such occurrences.

The process of joining separated mercury columns consists of one or a series of manipulations:

a) The bulb of the thermometer may be cooled in a solution of common salt, ice, and water (or other cooling agent) to bring the mercury slowly down into the bulb. Only the bulb should be cooled and never the stem or mercury column. Moderate tapping of the bulb on a rubber stopper or similar soft spongy object, or the application of centrifugal force by swinging the thermometer in a short arc, usually serves to unite the mercury in the bulb. If the salt solution does not provide sufficient cooling, carbon dioxide snow (dry ice) may be used. Since the temperature of dry ice is about -78 °C and mercury freezes at about -39 °C, the mercury will solidify. On warming, care must by taken to warm the top of the bulb first so that pressures in the bulb due to the expanding mercury may be relieved.

b) The mercury can sometimes be reunited by warming the bulb until the column reaches the separated portion in either the contraction chamber or the expansion chamber. If this procedure is used, the bulb should never be heated in an open flame. Great care is necessary to avoid filling the expansion chamber completely with mercury which might produce pressures great enough to burst the bulb. The expansion chamber should never be more than two-thirds full. Joining the mercury is more readily accomplished if the quantity in either cavity has first been shattered into droplets by tapping the thermometer laterally against the hand.

Gas bubbles, which are sometimes found along the surface of the mercury in the thermometer bulb, may be collected by "washing" the bulb with a large gas bubble. As outlined in section (a) above, bring all of the mercury into the bulb. Hold the thermometer in a horizontal position and gently tap it against the hand to form a large gas bubble. Force the bubble to travel around the wall of the bulb by rotating the thermometer and tapping it against the palm of the hand. When the entire surface has been "washed," rotate the bubble to the top of the bulb and reunite the mercury as described above.

All of these manipulations require patience (and experience is helpful) but they will yield the desired results if care is used. A convenient method of ascertaining that all the mercury has been joined is a check of the ice point. It should agree with the ice-point reading on the Report of Calibration by within approximately one scale division or better.

B. ICE POINT DETERMINATION

The ice point, known as a reference point, is found on the auxiliary scale. It is a temperature that can be easily duplicated in any laboratory and is used to check the thermometer periodically for changes in bulb volume.

To make an ice bath, a Dewar flask may be used as a container, since the insulating properties of the vessel retard the melting of ice. Ice shaved from clear cakes or from that made with distilled water is mixed with distilled water to form a tightly packed slush. Enough water is used to afford good contact with the thermometers but not so much as to float the ice. At periodic intervals excess water is siphoned from the bath. Care should be taken to prevent contamination of the ice and water. Any change in the ice point will be reflected in the other calibration points by the same amount and in the same direction. An example is given below:

Original Corrections From NIST Report

Thermometer Reading	Correction
-0.013 °C	+0.013 °C
25.000 °C	+0.010 °C
30.000 °C	+0.008 °C
37.000 °C	+0.015 °C

A later ice-point reading, taken after the thermometer has been at a temperature of about 23 °C for not less than 3 days, may be -0.020 °C. This means that the ice-point correction will be +0.020 °C and a new set of corrections should be made by adding +0.007 to all of the original corrections. The new table would look as follows:

Thermometer Reading	Correction
-0.020 °C	+0.020 °C
25.000 °C	+0.017 °C
30.000 °C	+0.015 °C
37.000 °C	+0.022 °C

Because of bulb expansion, a temporary ice point depression will be introduced when the thermometer is heated above room temperature (23 °C). Because of this depression, the thermometer should never be used at a given temperature shortly after it has been heated beyond that temperature. An error of 0.01 °C or less for each 10 °C difference between the two temperatures may be introduced. If the thermometer has been heated beyond the temperature at which it is to be used and if the corrections are to be used as given on the Report of Calibration, it must be kept at room temperature (approximately 23 °C) for not less than 3 days to assure recovery of the bulb.

A small reading telescope with a magnification of 10 diameters aids in reading the thermometer indication and reduces parallax errors. Gently tapping the thermometer just before reading may prevent the sticking of a falling meniscus. On the other hand, too vigorous a tap will occasionally cause the mercury to rebound to an erroneously high reading.

C. EMERGENT-STEM CORRECTION

The scale corrections for SRM 934 are reported for the condition of immersion to the depth of the immersion mark (95 mm), and for the temperature of the emergent stem as reported on the Report of Calibration. The emergent stem is defined as the length of mercury column and stem exposed to the ambient temperature. The temperature of the laboratory was 23 °C when the measurements were made. If the thermometer is used under stem-temperature conditions other than that specified, the formula given below will provide the appropriate correction, which should be added to the thermometer reading along with the correction from the Report of Calibration to produce the true temperature.

$$\text{stem correction} = 0.00016\ n\ (t_{sp} - t_{obs}),$$

where

0.00016 = differential expansion coefficient of mercury in glass for Celsius thermometers,

t_{sp} = specified mean temperature of the emergent stem (for which reported scale corrections apply)

t_{obs} = observed mean temperature of the emergent stem, and

n = number of scale degrees equivalent to the length of emergent stem.

In using the formula it should be noted that n applies to the whole length of emergent stem, i.e., from the immersion mark to the top of the mercury column. The ungraduated length between the immersion mark and the first graduation on the scale must, therefore, be evaluated in terms of scale degrees and included in the value of n.

To measure the emergent-stem temperature, a small auxiliary thermometer, generally 15-cm long with a range from 0 °C to 100 °C and graduated in 1 °C intervals, is suspended above the bath adjacent to the main thermometer, with the bulb approximately at the center of the liquid column.

For SRM 934, a 2 °C temperature difference in the stem temperature would produce the following results, assuming n approximately equals 4.4, 9.4 and 16.4 for 25 °C, 30 °C, and 37 °C,

Temperature		Correction
25 °C	0.00016 x 4.4 x ± 2 =	±0.0014 °C
30 °C	0.00016 x 9.4 x ± 2 =	±0.0030 °C
37 °C	0.00016 x 16.4 x ± 2 =	±0.0052 °C

To help clarify any difficulty that may remain, an example of how to apply the corrections is given below:

Thermometer = SRM 934
The reading of the thermometer (immersed 95 mm in the bath) = 30.013 °C,
Measured emergent-stem temperature = 29 °C,
Number of degrees from immersion mark to point of reading (30 °C) = 9.4,
Correction on the Report of Calibration at 30 °C = -0.019 (stem temp. = 26 °C).
An ice point check produced the same result as shown on the Report of Calibration.

First, find the stem-temperature correction:

$$\text{stem correction} = 0.00016 \times n \times (t_{sp} - t_{obs})$$

$$= 0.00016 \times 9.4 \times (26 - 29)°C$$

$$= - 0.005\ °C$$

True temperature = thermometer reading + stem correction + reported correction

$$= 30.013 + (-0.005) + (-0.019)°C$$

$$= 29.989\ °C$$

V. SUMMARY AND CONCLUSIONS

In order to obtain the accuracy of temperature measurements of which SRM 934 is capable, the following items should be closely observed:

1) check for a separated mercury column and for gas bubbles in the bulb,
2) check the ice point periodically for changes in the bulb volume,
3) always use the thermometer at the proper immersion (95 mm),
4) correct for emergent-stem temperatures different from those listed in the Report of Calibration,
5) gently tap the thermometer before reading, and
6) read with a telescope, if possible, to avoid parallax errors.

With the introduction and use of SRM 934 in the typical clinical laboratory, there will be a marked improvement in the laboratory's measurement capability. The thermometer will provide a means by which the laboratory personnel can make a start toward eliminating any uncertainty in their testing which is due to inaccurate temperature measurement and, in many cases, its control. This will assist efforts at improving measurement reproducibility within a given laboratory and intercomparisons among laboratories.

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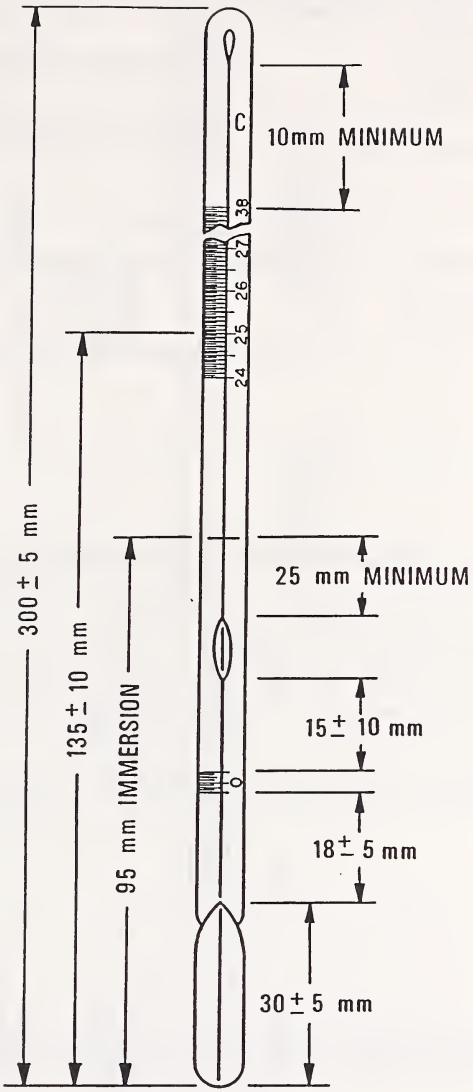

Figure 1. The thermometer of SRM 934. The divisions are 0.05 °C and the graduations have longer lines at intervals of 0.10 °C and 0.50 °C.

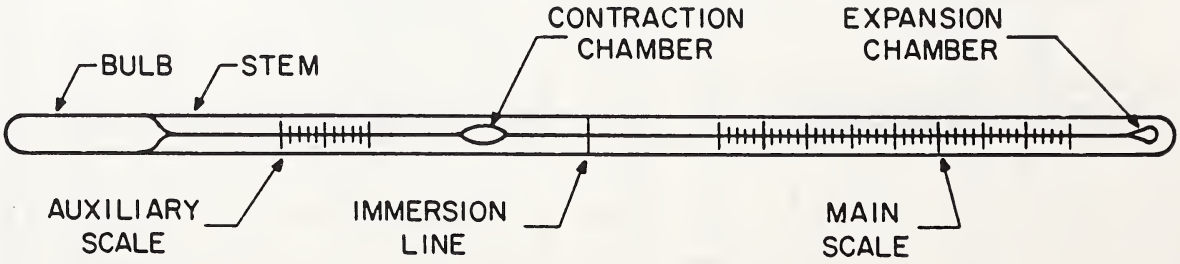

Figure 2. A drawing showing the principal features of a solid-stem liquid-in-glass thermometer.

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Because of the high sensitivity to temperature of many facets of the clinical laboratory, e.g., in enzyme reactions and in pH and blood gas analysis, there is a need for accurate temperature measurement and its control. In order to help satisfy these needs and to aid in getting a usable and accurate temperature scale into the clinical laboratory, the National Institute of Standards and Technology developed SRM 934. This is a precision thermometer that is calibrated at 0 °C, 25 °C, 30 °C, and 37 °C. The description, calibration, and the procedures for proper usage of this thermometer are discussed.

This SP 260 supersedes SP 260-48 describing both SRMs 933 and 934. SRM 933 will no longer be issued by the SRM Program. This publication is the same as SP 260-48 with the exception that all references to SRM 933 have been removed.

KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

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